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# READING RATE AND COMPREHENSION: IMPLICATIONS FOR DESIGNING COMPUTER TECHNOLOGY TO FACILITATE READING COMPREHENSION

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**Abstract**: *The article presents findings from recent research on reading rate, comprehension and subvocal speech. It discusses how computer assisted software could be used to assist readers in developing reading strategies that can help them become more proficient readers. It also discusses implications for software development that takes into account the recent findings on reading rate and subvocal speech.*

**1. Introduction:** Whether we are teaching seventh grade English, tenth grade social studies or college level science, as educators we have all encountered students who read the words in the text but have very little understanding of what they have read. It seems as though many students are unaware of how to gain meaning from the written text. How can we assist readers in becoming more aware of the complex processes involved in reading for meaning? This paper presents research findings which provide insight into what readers do when they are processing text. It explores the role of subvocal speech, reading rate and comprehension and discusses how this research could guide the development of computer technology designed to improve reading and comprehension skills.

**1.1. Subvocal speech**: During the past one hundred years, there has been considerable research on the role of subvocal speech during silent reading. (Carver, 1990; Edfeldt, 1960; Huey, 1908). Some investigators (Rubenstein, Lewis & Rubenstein, 1971; Gough, 1972) have theorized that readers translate the printed word into its corresponding phonological code which is used to access meaning. Experimental paradigms and sophisticated apparatus have contributed to examining the processes that occur during silent reading (Rubenstein *et al*, 1971, McGuigan & Winstead, 1974). In a recent study, Freese (1996) investigated the relationship of subvocal

speech to reading rate and comprehension by means of electromyographic (EMG) recordings taken while participants (25 children) silently read two meaningful passages. Results from the study provided support for the role of subvocal speech as an aid to comprehension. The regression model predicting reading age suggested a developmental aspect for subvocal speech. That is, subvocal speech is more important in the earlier stages of reading. And as a reader becomes more proficient, subvocal speech becomes less overt.

**1.2. Reading rate**: Reading rate has also been an area of research that has aroused considerable interest (Carver, 1990, Just & Carpenter, 1980; Huey, 1908). Results from the previous study (Freese, 1996) indicated that successful readers demonstrated flexibility in their reading as shown by their EMG activity levels and time taken to read the two passages. The purpose of this paper is to analyse the data derived from the previous study by using Carver's reading model (Carver, 1990, 1992) to systematically explore the relationship between reading rate and comprehension, and investigate the reading processes the participants used when they silently read the two passages. Carver (1990) theorized that reading involves five basic processes: memorizing (Gear 1), learning (Gear 2), rauding (Gear 3), skimming (Gear 4) and scanning (Gear 5) (Carver, 1990, p.440). Rauding is defined as an individual's typical reading rate which includes sentence integration and adequate comprehension and is the basic process readers use most of the time.

An individual's reading rate may vary depending on the difficulty level of the material and purpose of the reader (Carver, 1992, 1984). For example, a reader may use the skimming process when he only needs an overview of the material as opposed to comprehension. A reader may shift to another process (learning) when the material is relatively difficult and he needs to reread or back up in order to understand the material.

## 2. Method

**2.1. Participants**: Twenty-five students, fifteen girls and ten boys, ranging in chronological age from eight to fifteen years, participated in the experiment. One participant was eliminated due to aberrant EMG readings. All of the participants read at the fourth grade level

or above. Students who did not read at the fourth grade level, as measured by the Dale Chall Reading Test, were ineligible to participate because the passages used in the experiment were at the fourth grade level.

**2.2. Passages**: Two passages were used in the study: a regular passage and an experimental passage. The regular passage consisted of 249 actual words and 231 standard length words. The actual word length was converted to standard word length by using Carver's (1992) formula which defines standard length word as six character spaces long, including letters, punctuation and spaces. The experimental passage, constructed by the experimenter, consisted of 233 actual words and 207 standard length words. Again, the conversion was done using Carver's formula (1990, p.9). The experimental passage involved meaningful, connected text which consisted of 60% homophones. The following is an example of text taken from the homophone passage: 'Hour new made was called Gene. She was two bee at hour house by ate that mourning. Wear mite she bee? Had she mist the write tern onto hour rowed?'

The readability level of both passages was 4.0 and 4.3 as measured by the Dale Chall Readability Scale. The homophone passage was considered more difficult because of the ambiguity of the homophones, the phonetic similarity and visual dissimilarity. This passage was particularly suited to the study of subvocal speech because the reader could not rely on a visual code to gain information as he silently read the homophone passage. The reader was required to take the individual units one by one and integrate them to gain meaning from the passage. The passages were suited to studying how readers process textual material of varying difficulty.

**2.3. Procedures**: The participants were tested individually. The study utilized EMG recordings and the carefully constructed homophone passage. Each individual participated in a pre-experimental (practice) session five days before the formal experiment. This was done to familiarize the participant with the experimental apparatus and procedures. During the pre-experimental and experimental phases of the experiment, the subjects' reading rates, comprehension scores and EMG levels of activity in the upper lip area were measured. (See Freese, 1996 for a complete description of the experiment.) It should be noted that the

EMG data was not central to the analysis of the data in this follow-up study.

Participants were required to read the standardized passage and the experimental (homophone) passage. Participants were instructed to silently read the passages in a natural manner and advised that comprehension questions would follow. Twelve comprehension questions, testing basic recall of facts, were administered to each participant on the regular and homophone passages.

The study was designed to create a situation which would require the participants to read the regular passage at a normal, natural rate with comprehension. Applying Carver's model (1990), this rate would presumably be similar to their rauding rate. It was theorized that the participants would increase their level of subvocal speech when reading the homophone passage, and decrease their reading rate. The homophone passage was considered more difficult and would require more time to access the meaning.

**2.4. Data analysis**: Reading rates were derived for both the homophone and regular passages using the standard word length formula (Carver, 1992). Individual reading rates were calculated for each participant by dividing the number of standard words in each passage by the time taken to read the passage. For example, the rate on the homophone passage was calculated by dividing the number of standard words (207) in the passage by the time it took the participant to read the passage. Similarly, the rate on the regular passage was calculated by dividing the number of standard words (231) by the time taken to read the passage. The reading rates are reported as standard words per minute, wpm, (Carver, 1992). See Table 1 for the reading rates for each participant.

Rauding rates were estimated for each participant using Taylor's (1965) reading rate and grade equivalent data, as well as Carver's rates which used standard length words and Taylor's data (Carver, 1990, p.463). The resulting equivalency data provided an operation-al way to estimate the rauding rates for each participant using their reading ages. The estimated rauding rate was used to predict the rate at which the reader would typically read text with under-standing. Estimated rauding rates for all participants in this study are shown in Table 1. Carver allows that there may be variability in rate among students in the same grade (Carver, 1978).

Since the goal was to read the passages with understanding, the comprehension scores on the homophone passage were an important indicator as to whether the participant integrated the individual units (homophones) to gain meaning. Using the homophone comprehension scores (number correct out of 12), the participants were ranked and divided into two categories, high comprehenders and low comprehenders. The median comprehension score (7.5) on the homophone passage was used as the cut-off to differentiate the high comprehenders from the low comprehenders. The high comprehenders scored 8 or higher on the homophone test and the low comprehenders scored 7 or below. See Table 1, column 3, for the distribution of the high and low comprehenders.

The reading rates (wpm) of each participant on the homophone passage and the regular passage were compared to their estimated rauding rate. A resulting percentage was calculated to indicate at what percent of their rauding rate they read the regular passage, and at what percent of their rauding rate they read the homophone passage. Results indicated that the readers above the median, 8 or higher, read the regular passage at 91% of their rauding rate. They read the homophone passage at 54% of their rauding rate. The data suggested that the readers adjusted their reading rate when reading the homophone passage.

On the other hand, the readers with homophone comprehension below the median, seven and below, read the regular passage at 86% of their rauding rate. They read the homophone passage at 70% of their rauding rate. The data suggested that the low comprehenders, those below the median, did not adjust their rate on the homophone passage to the degree that the more proficient readers did. The data indicated a minimal amount of shifting gears and low comprehension. See Table 1.

**3. Discussion**: What did the successful readers do differently from the less successful readers? The more proficient readers monitored their comprehension on the homophone passage and, in keeping with Carver's model, they shifted gears upon realizing they needed to shift from their rauding rate to another gear, i.e. learning gear. Successful readers appeared to demonstrate process flexibility by shifting to the appropriate strategy when the task demanded it. The findings support Carver's theory (1992) that proficient readers are flexible in applying reading processes. They can shift from the

| | | Comprehension | | Rate (wpm) | | | % Rauding* | |
|---|---|---|---|---|---|---|---|---|
| Student | RA† | Homo† | Reg† | Rauding‡ | Homo† | Reg† | Homo† | Reg† |
| 1 | 6.1 | 11.0 | 11.0 | 170 | 133 | 80 | 78 | 47 |
| 2 | 7.6 | 10.0 | 11.0 | 191 | 133 | 83 | 70 | 43 |
| 3 | 8.0 | 9.5 | 9.5 | 195 | 155 | 103 | 79 | 53 |
| 4 | 8.0 | 9.5 | 9.0 | 195 | 133 | 103 | 68 | 53 |
| 5 | 8.5 | 9.5 | 8.0 | 205 | 186 | 103 | 91 | 50 |
| 6 | 9.2 | 9.0 | 6.0 | 210 | 186 | 55 | 89 | 49 |
| 7 | 7.0 | 8.5 | 9.0 | 185 | 186 | 118 | 100 | 64 |
| 8 | 7.6 | 8.5 | 8.5 | 191 | 155 | 138 | 81 | 72 |
| 9 | 5.2 | 8.5 | 8.5 | 160 | 155 | 92 | 97 | 57 |
| 10 | 4.7 | 8.0 | 3.5 | 149 | 233 | 75 | 156 | 50 |
| 11 | 4.5 | 7.5 | 11.0 | 149 | 186 | 138 | 125 | 93 |
| 12 | 7.0 | 7.5 | 9.0 | 185 | 104 | 103 | 56 | 56 |
| 13 | 5.5 | 7.5 | 6.0 | 163 | 104 | 75 | 64 | 46 |
| 14 | 5.4 | 7.0 | 10.0 | 163 | 85 | 55 | 52 | 34 |
| 15 | 4.5 | 7.0 | 8.5 | 149 | 133 | 92 | 89 | 62 |
| 16 | 5.1 | 7.0 | 7.5 | 155 | 117 | 92 | 75 | 59 |
| 17 | 4.0 | 7.0 | 2.5 | 140 | 104 | 69 | 74 | 47 |
| 18 | 6.7 | 6.0 | 8.5 | 177 | 186 | 138 | 105 | 128 |
| 19 | 5.4 | 6.0 | 8.5 | 163 | 186 | 138 | 114 | 85 |
| 20 | 5.8 | 5.0 | 10.0 | 165 | 155 | 138 | 94 | 84 |
| 21 | 6.4 | 5.0 | 7.0 | 177 | 117 | 92 | 66 | 52 |
| 22 | 4.3 | 3.0 | 9.0 | 145 | 155 | 138 | 107 | 95 |
| 23 | 6.4 | 3.0 | 5.5 | 175 | 133 | 118 | 76 | 67 |
| 24 | 4.0 | 3.0 | 4.5 | 140 | 133 | 75 | 95 | 54 |

*passage reading rate ÷ rauding rate × 100
†RA = reading age; Homo = homophone passage; Reg = regular passage
‡Rauding = typical student's reading with understanding rate

Note: Participants with homophonic comprehension scores above the median (7.5) read the regular passage at 91% of their rauding rate and read the homophonic passage at 54% of their rauding rate. Participants with comprehension scores below the median read the regular passage at 86% of their rauding rate and the homophonic passage at 70% of their rauding rate.

**Table 1. Participants' raw data: reading age, comprehension scores, reading and rauding rates.**

'rauding process' into another gear when the reading goal requires it. That is, they adjusted their reading rate when they encountered the more difficult material (homophonic passage).

The less successful readers did not appear to shift their rate very much on the homophone passage. Whereas the more successful readers decreased their reading rate on the homophone passage to about half of their rauding rate, the less successful readers decreased their rate slightly from the regular passage to the homophone passage, from 86% to 70%. They did not shift their strategy when the task required it. Given that many of the low comprehenders also had low levels of subvocalization as measured by the EMG recordings, the low comprehenders may have been skimming or scanning the text, and consequently were unsuccessful at gaining meaning from the text.

The analysis using Carver's (1990) research provided additional insight into the relationship between reading rate and comprehension. The rauding rate provided a systematic way of looking at the participant's ability to adjust their reading process in order to gain comprehension. By comparing the participants' experimental reading rates to their rauding rates, interpretations could be made about what the readers were doing and what type of reading processes they were they using. The analysis of the data supported the earlier findings (Carver, 1992, Freese, 1996) and extended the interpretation of the relationship of reading rate to comprehension.

Additionally, the analysis showed that reading age alone did not distinguish the more successful readers from the less successful ones. The findings could have implications for software development and reading instruction. Teachers should make explicit to students that reading involves a number of different processes and provide opportunities for students to practice using the different processes (gears) outlined in Carver's model (1992). By doing so, students may gain a keener awareness of what they are doing when they read, and when they should shift gears. By practicing reading a variety of materials for different purposes and with specific goals in mind, readers may develop a level of automaticity in their reading that enables them to shift gears when the situation and goal require it.

**4. Implications for software development**: Given these latest findings, what are the implications for computer software? It is

believed that by taking advantage of the latest developments in computer technology, software could be designed to help readers of different ability levels become aware of the various strategies or reading processes they engage in when reading. The software could include an element of drill and practice to help students develop automaticity and flexibility in their reading for comprehension. And, it could go beyond drill and practice by taking into account the students' reading rates. It could provide opportunities to practice different reading processes with texts of various difficulty levels. Students could gain feedback on their reading rates and comprehension levels as well as insight into what strategies they are using and how they process the text. Using this information, the students could modify their reading rate and shift reading strategies depending on the material and the purpose for reading.

The software could incorporate an interactive aspect that guides students to analyze their reading processes and helps them make connections between what they do when they read, their purposes for reading and their level of comprehension. Given the rapid pace of development in computer technology, the prospects are encouraging for computer applications in the area of improving reading comprehension which could be used inside and outside the classroom.

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